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MEASUREMENTS OF EROSION CHARACTERISTICS FOR METAL AND POLYMER SURFACES USING PROFILOMETRY

Ligia C. Christl and John C. Gregory
The University of Alabama in Huntsville*
Huntsville, Alabama 35899
Phone: 205/895-6840, Fax: 205/895-6349

P12
AM 584056

Palmer N. Peters
Space Science Laboratory, NASA/MSFC
Huntsville, Alabama 35812
Phone: 205/544-7728, Fax: 205/544-7754

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SUMMARY

The surfaces of many materials exposed in low earth orbit are modified due to interaction with atomic oxygen. Chemical changes and surface roughening effects can occur which alter optical and other properties (ref.1). The experiment A0114 contained 128 solid surface samples, half of which were exposed on the front and half on the rear of LDEF. Each sample has been subjected to many analyses, but this paper will only describe the methods and techniques used to measure the changes in roughness, erosion depths and material growth using profilometry.

INTRODUCTION

The effect of atomic oxygen on materials is highly variable. No method of measuring the effects is optimum for all materials. We have developed several techniques found valuable in analyzing a wide range of materials, varying from minute effects on the level of atomic dimensions to heavily etched surfaces. One of the most effective techniques has been to utilize the measurement of etched steps at interfaces between exposed and unexposed, or masked, areas by stylus profilometry. Stylus profilometers typically measure the vertical displacement of a stylus (usually a fine pointed diamond) as it is scanned horizontally across the surface. Highly magnified vertical displacements are plotted against horizontal positions greatly exaggerating surface detail. This technique has the ability to measure a wide range of etch steps, from below 1 nm to 1 mm. For measurements below 1 nm it is essential that optically flat surfaces be used and that the steps be measurable over very short lateral distances. As shown elsewhere (ref.2), to produce etch steps over short lateral distances requires very thin masks, preferably thin film patterns resistant to atomic oxygen that are strongly bonded to the substrate being exposed, or at least knife-edged masks essentially in contact with the surface; these types of mask avoid structures which

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accurate measurements of the spikes or plateaus that form at locations of slower etch, and provides an estimate of the maximum etch depth.

Polymethylmethacrylate, PMMA, is a plastic which is readily etched by atomic oxygen, forming a large number of small spikes at the bottom of the etch and a large etch step, as shown in Figure 10, and Figure 11. Figure 10, was traced on a sample mounted on the ambient temperature plate and Figure 11 is for a sample mounted on a separate thermally isolated plate of semipolished aluminum. The purpose was to examine the etch rate as a function of temperature. The small increase in etch in Figure 11 may be due to slightly higher temperature of the hot plate sample. The smooth plateau at the right of the etched area in Figure 10 is due to an artefact caused by the stylus catching on the large etch step and dragging the sample a short distance; heavily etched samples need to be secured for this reason.

CONCLUSION

Stylus profilometry is a very effective non destructive or minimal scratching technique to measure roughness, erosion depth and material growth of metals, polymers and carbons exposed to the atomic oxygen.

We have demonstrated that these instruments (Talystep and Talysurf), used in combination with some of the techniques mentioned (scratching, step and transition measurements), have a wide range of resolutions, from $\sim 1\text{\AA}$ to a few hundred microns.

Examples, like iridium film, show the reliability of the instrument, giving the same thickness value for the transition in any direction scanned.

Stylus profilometry, by indicating decreases, or increases, in film thicknesses enables interpretations of changes in optical density measurements, i.e. whether thinning of the film or an increase in thickness with optical property changes are responsible for optical density changes.

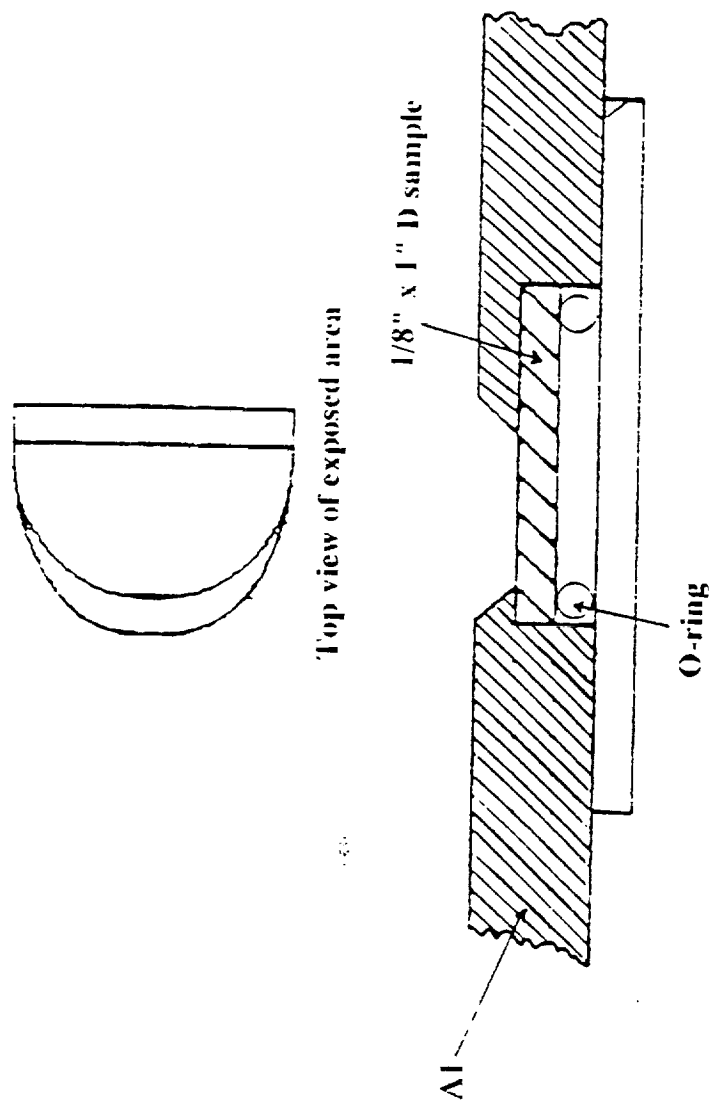
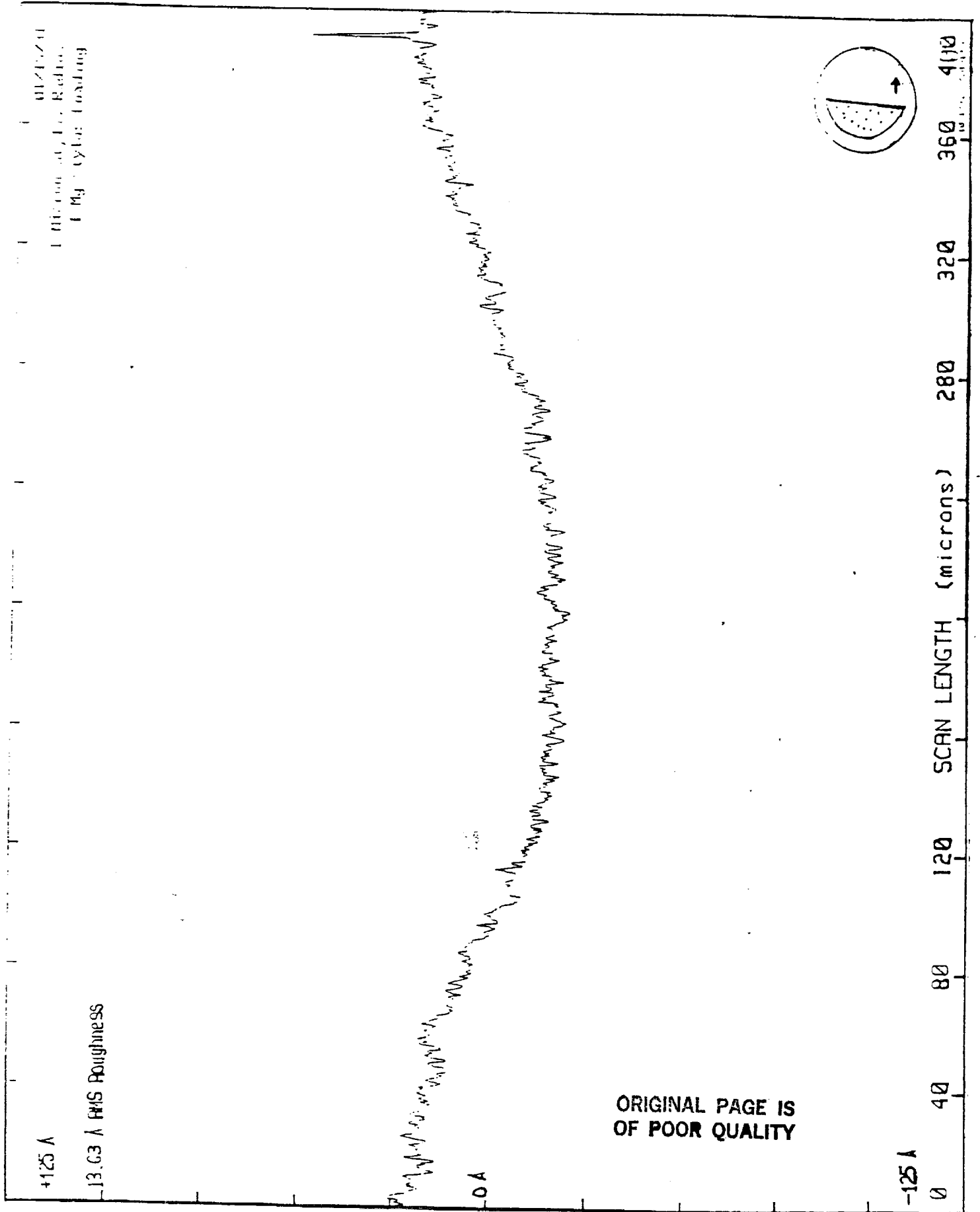


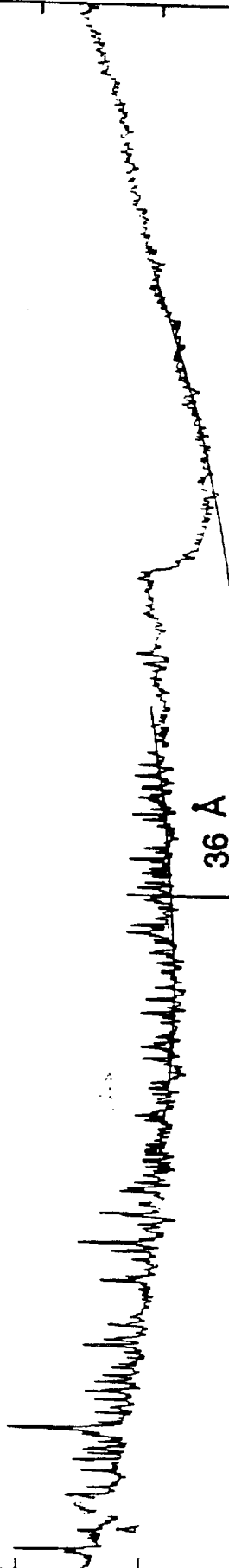
Figure 1. Cross-section of sample holder between exposed and unexposed areas



250 Å

12.67 Å RMS Roughness

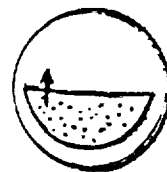
Micrograph of the surface
of the 100 Å film



36 Å

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OF POOR QUALITY

-250 Å



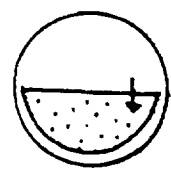
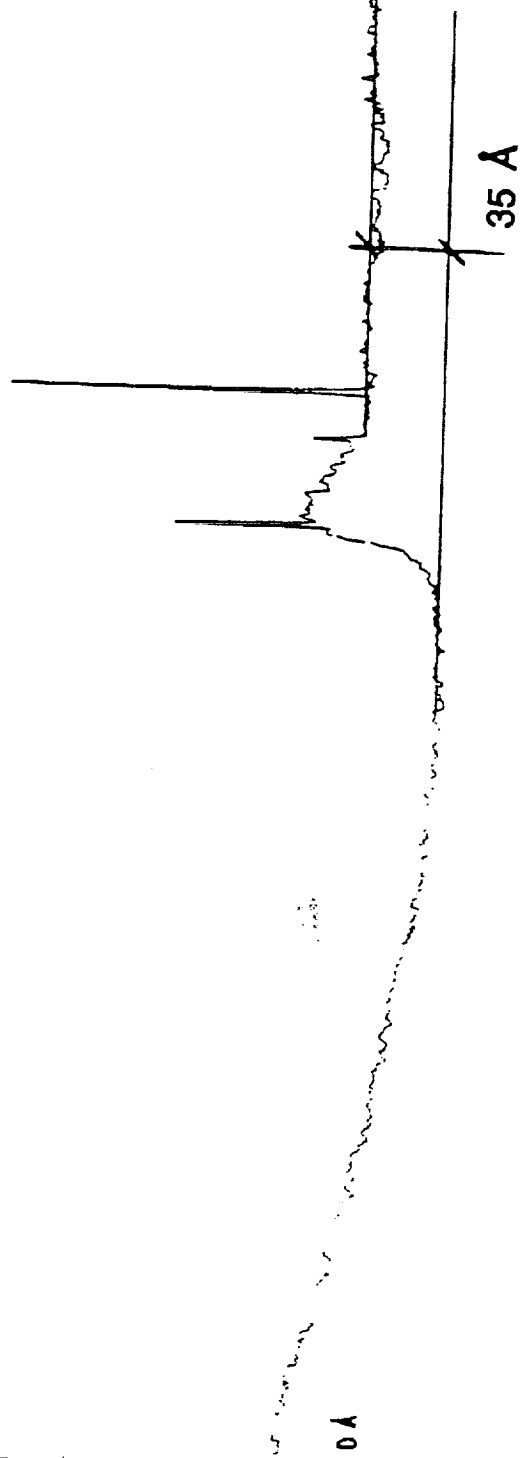
0 75 150 225 300 375 450 525 600 675 750

SCAN LENGTH (microns)

+312.5 Å

1082 Å RMS Roughness

01/15/91
1 Micron Stylus Radius
1 Mg Stylus Loading



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OF POOR QUALITY

312.5 Å

320

368

416

464

SCAN LENGTH (microns)

656

704

752

800

+625 Å

101.11 Å RMS Roughness

8/27/98
1 Micron Stylus Radius
1 Mg Stylus Loading

0 Å

316 Å

-625 Å

50

100

150

200

250

300

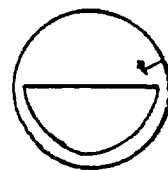
350

400

450

500

microns



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8/27/90
 1 Micron Stylus Radius
 1 Mg Stylus Loading

1625 Å

157.35 Å RMS Roughness

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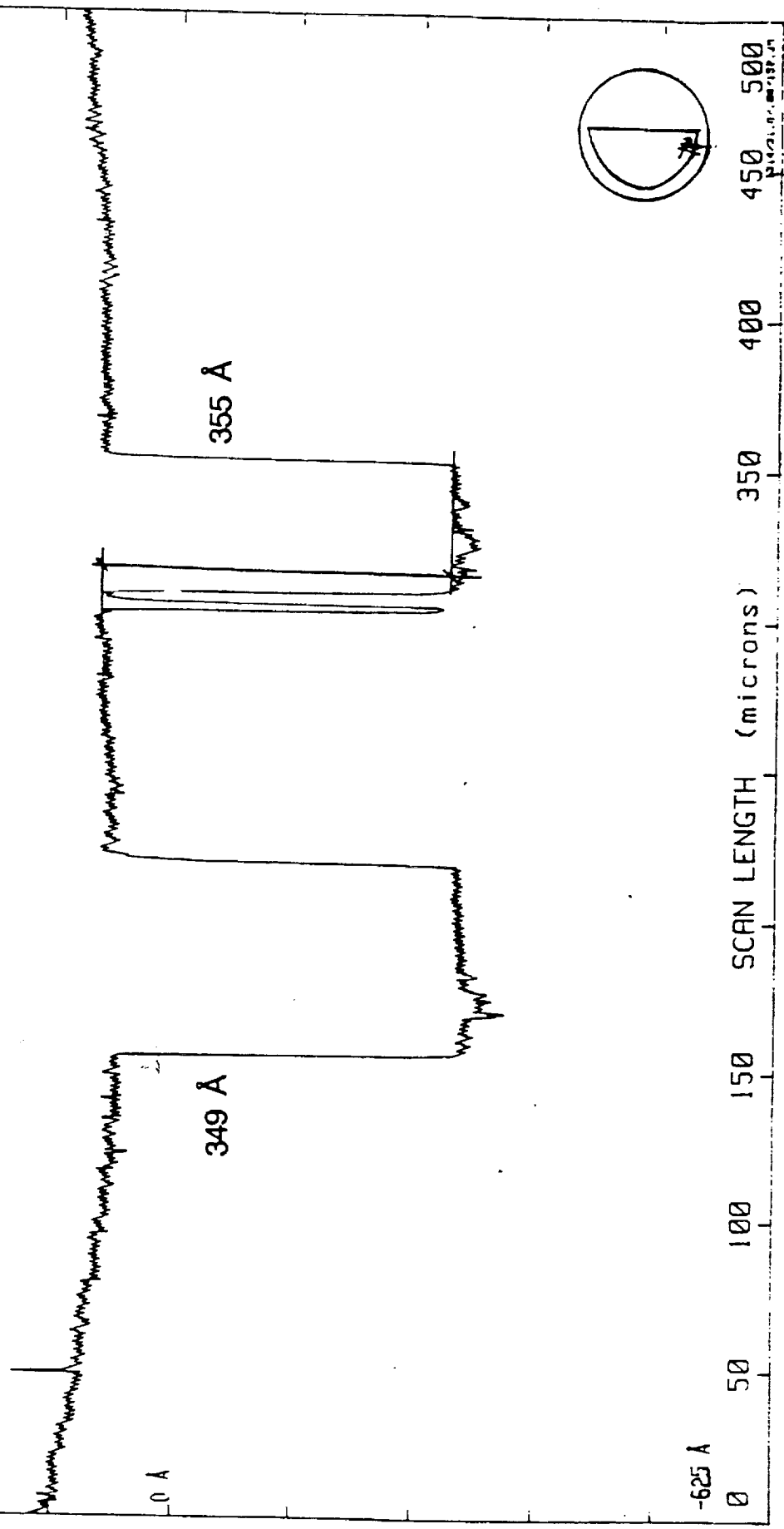
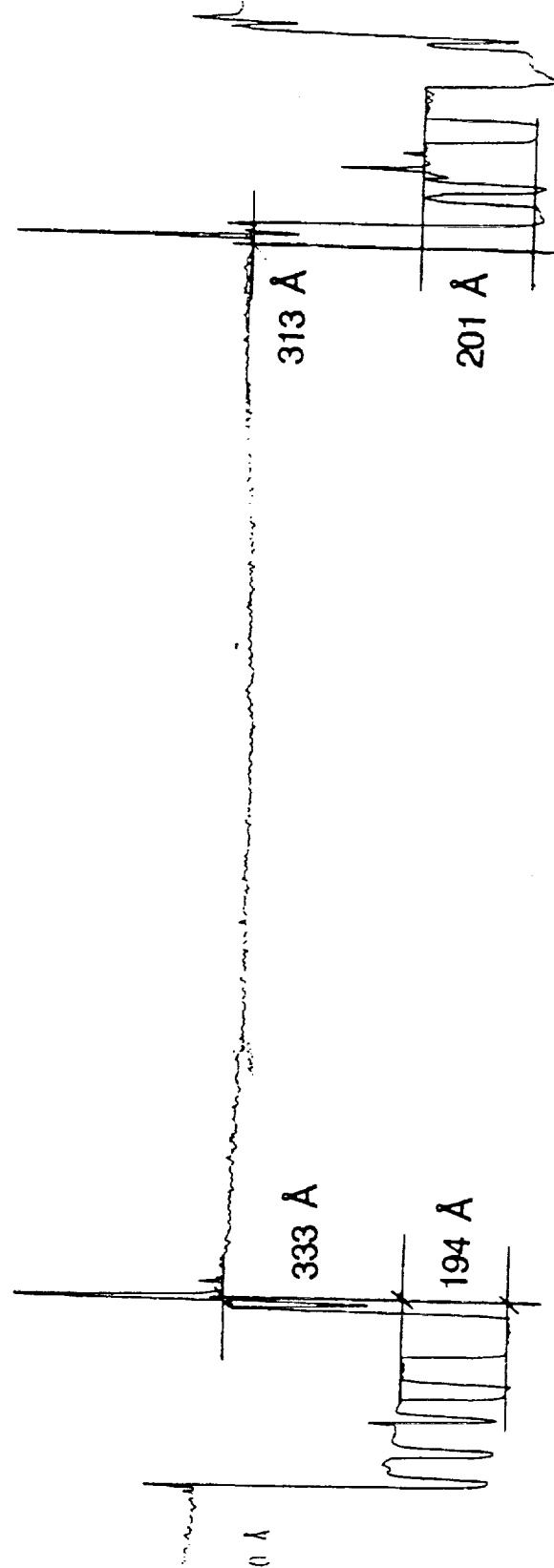


Figure 6 Surface roughness of annealed Cd film

11.50 Å

175.47 Å RMS Roughness

11/27/80
1 Micron Stylus Radius
1 Mg Stylus Loading



1250 Å

100

150

200

250

300

350

400

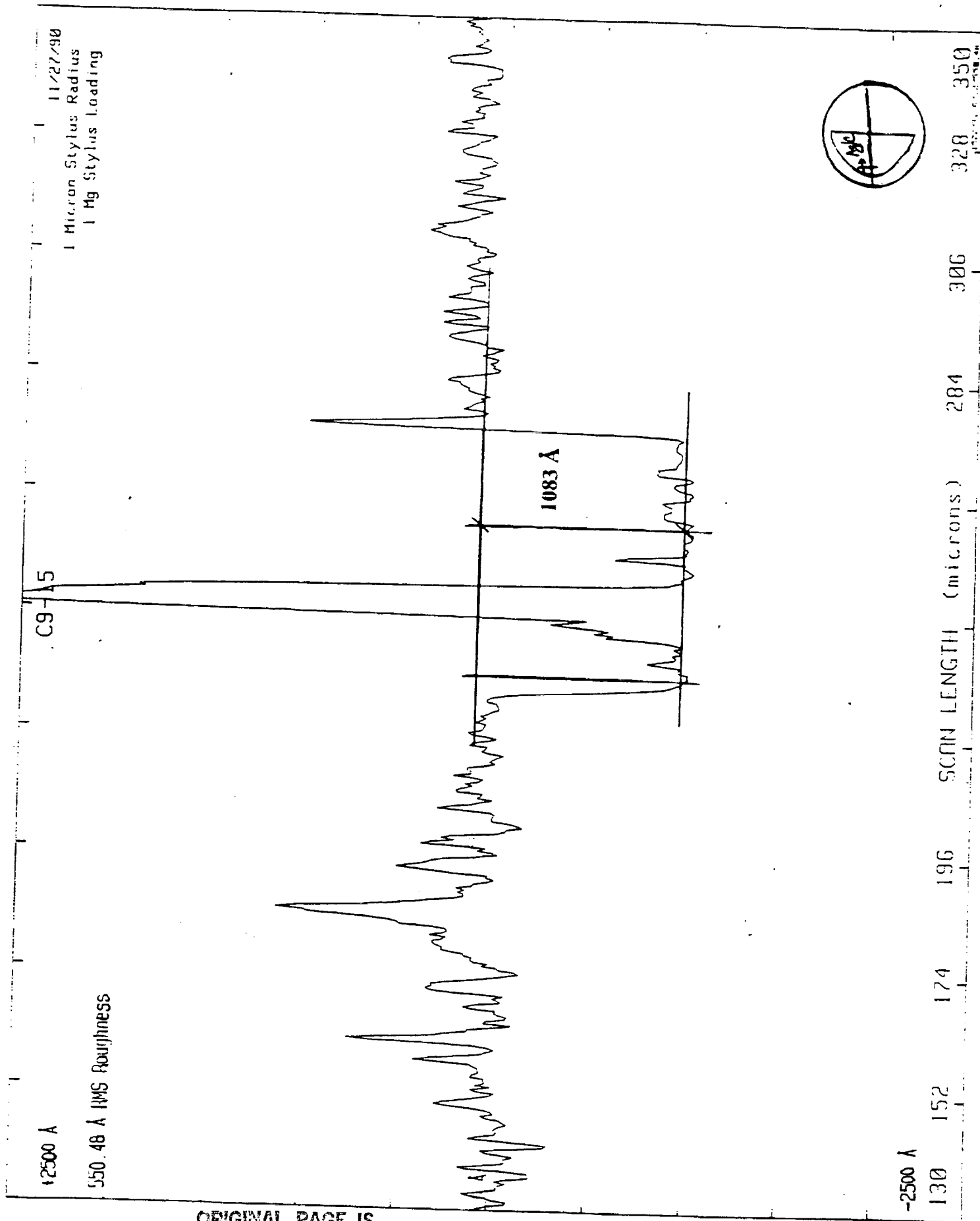
450

500

550

600

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Polycrystalline Carbon (C9-05)

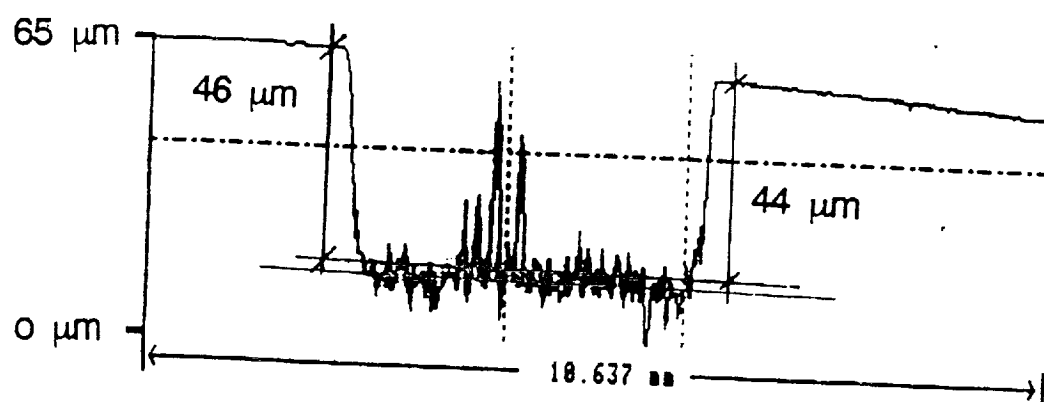


Figure 9. Surface profile of Polycrystalline Carbon

PMMA (C9-31)

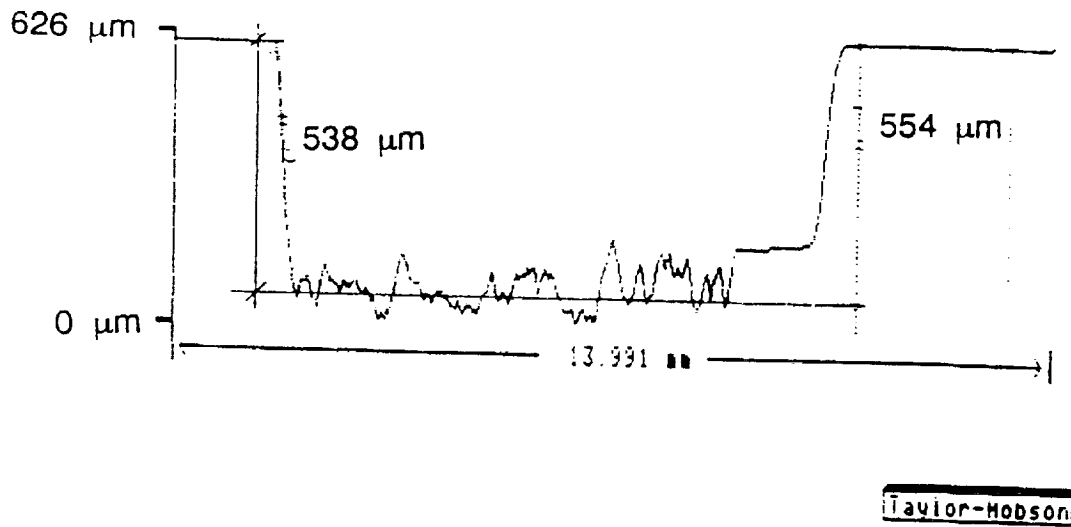


Figure 10. Surface profile of Polymethylmethacrylate at ambient temperature

PMMA (C9H-03)

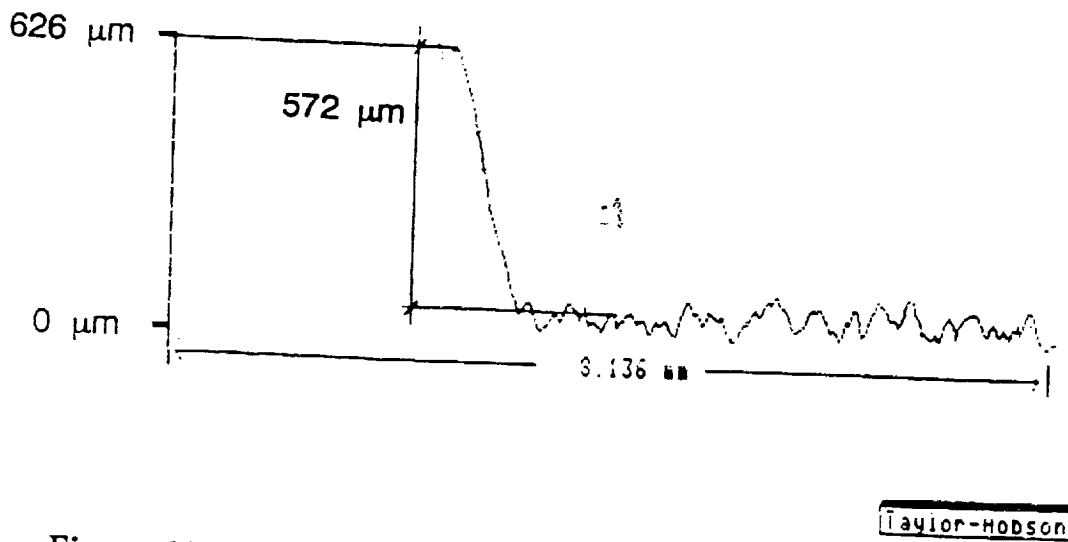


Figure 11. Surface profile of Polymethylmethacrylate at 10° C above the ambient temperature